Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 146 (2016) 530 – 535

Procedia Engineering

www.elsevier.com/locate/procedia

8th International Cold Climate HVAC 2015 Conference, CCHVAC 2015

Analysis of the Energy Consumption and Economic for Combined Heating Supply System Based on Groundwater Heat Pump and Boiler Plant

Kang Zhiqiang[a],Meng Qin[b],Yang Xue[a],Feng Guohui[a]*,Fan Hongbo[a],and Zhang Yixian[a]

[a]*School of Municipal and Environmental Engineering, Shenyang Jianzhu University,Shenyang,110168, China*
[b]*Architecture design and research institute of Shenyang Jianzhu University, Shenyang, 110168,China*

Abstract

The purpose of this paper is to provide the reasonable design of operation parameters for the combined heat-supply system by obtaining the optimal allocation proportion based on the groundwater heat pump and boiler plant. Combined with the engineering example, based on the groundwater heat pump and coal-consuming boiler, the optimal distribution proportion of the combined heat-supply system is obtained by energy consumption analysis for heat load duration graph, economic analysis with annual cost method and simulation of the combined system. Combined heating of coal-consuming boiler and groundwater heat pump in the optimal load distribution proportion not only reduces the initial investment of heat source system, but greatly reduces the total energy consumption, prolongs the performance period of the boiler, and improves the utilization efficiency of the boiler as well. Meanwhile, the combined system has the lowest annual cost and the best economy.

Peer-review under responsibility of the organizing committee of CCHVAC 2015

Keywords: Combined heat-supply system; Groundwater heat pump; Coal-consuming boiler; Allocation proportion

* Corresponding author. Tel.: 2469-0716; fax: 2469-0716.
E-mail address: fengguohui888@163.com

Peer-review under responsibility of the organizing committee of CCHVAC 2015
doi:10.1016/j.proeng.2016.06.391

1. Introduction

With the improvement of people's life and enhancement of environment protection consciousness, the heat-supply technology remains improving in order to improve its quality. At present, heating sources include thermal power plant, regional boiler room, decentralized boiler, heat pump and electric boiler and so on.-thermal power plant and regional boiler room are used most commonly and heating pump is the one that develops rapidly[1]. Generally, in order to fully use the saving energy performance of groundwater heat pump and reduce the initial investment of assistant heating source, another assistant heating source with low initial investment is selected when the groundwater source heat pump system is designed[2].In this paper, considering energy consumption and economic investment, based on the groundwater heat pump and coal-consuming boiler, the energy consumption and economy are analyzed for present heating forms and features in northeast severe cold areas in our country.

Nomenclature

Q_{tx}	the heating load at temperature t_x, Mw
t_n	the indoor designing temperature , ℃
t_w	outdoor calculating temperature,℃
Q_n	design heating load, Mw
Q_{zh}	annual heating supply quantity of basic heating source, GJ
Q_f	annual heating supply quantity of assistant heating source, GJ
h_k	the start temperature of assistant heating source,℃
h_c	the lasting hours of assistant heating source after starting, h
A_c	the annual cost,Yuan
C_i	the initial investment, Yuan
i	the recovery coefficient, 10%,
n	the life period,20 years.

2. Methods

Based on groundwater heat pump and boiler plant, the paper takes the combined heating supply system of the same heating residential area community in Shenyang city and Harbin city as the research object. The optimal allocation proportion of the system is obtained when use the heat load duration graph to analyze energy consumption and annual cost method to analyze the economy. With numerical simulation of the combined heat-supply system based on groundwater heat pump and boiler, the energy consumption and economy of the system are analyzed. Combined with the engineering example, the paper analyzes the total energy consumption, annual cost, the optimal distribution proportion based on the combined system with different heating supply regions in the same area.

2.1. The energy consumption analysis

With same heating load, the energy consumption of groundwater heat pump is different from the boiler plant, when they operate respectively. The calculated total energy consumption varies with the load proportion changing separately during the whole heating period, when the both are combined operating. Thus, the allocation proportion corresponding with the low total energy consumption can be considered as the first important factor .Combined with the analysis on economic results, operating time of boiler, rate of total energy consumption variation, boiler tonnage etc. The optimal allocation proportion of the combined heat-supply system can be determined finally. During the whole heating period, the formulas of combined heat-supply system based on the groundwater heat pump and coal-fired boiler with different distribution proportion are as follows[1].

$$Q_{tx} = \frac{t_n - t_x}{t_n - t_w} Q_n \tag{1}$$

$$Q_{\mathrm{zh}} = 3.6 \times \sum_{t_x=5}^{t_c} \frac{t_n - t_x}{t_n - t_w} \times Q_n \times \Delta h_{tx} + 3.6 \times \frac{t_n - t_c}{t_n - t_w} \times Q_{\mathrm{n}} \times h_c \tag{2}$$

$$Q_{\mathrm{f}} = 3.6 \times \sum_{t_x=t_c}^{-19} \frac{t_n - t_x}{t_n - t_w} \times Q_n \times \Delta h_{tx} - 3.6 \times \frac{t_n - t_c}{t_n - t_w} \times Q_n \times h_c \tag{3}$$

With different allocation proportion, using the above formulas to calculate the annual heating load of the groundwater heat pump and boiler, the amount of standard coal consumption can be obtained [2].

2.2. Economic analysis

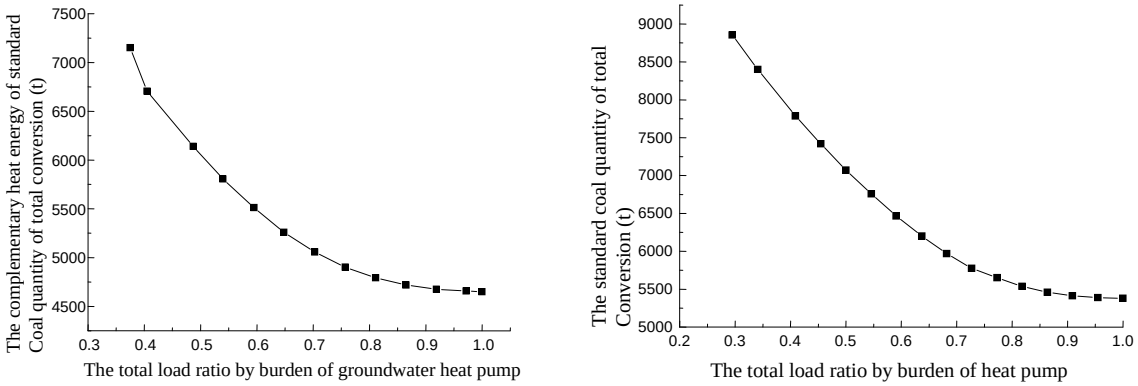
The paper analyzes the economy of the combined heat-supply system with the method of the dynamic annual cost [3]. With the same annual heating load and different allocation proportion, based on the minimum annual cost of the groundwater heat pump and coal-consuming boiler, the optimal allocation proportion is determined. The formula of annual cost is as follow:

$$A_c = C_i \left[\frac{i(1+i)^n}{(1+i)^n - 1} \right] + C_k \tag{4}$$

With the combined heating based on the groundwater heat pump coupled with the coal-consuming boiler plant, t he various inputs include equipment, fuel and so on. The total initial investment of the combined heat source and op erating cost of the system can lead to vary with the change of allocation proportion.

3. Example analysis

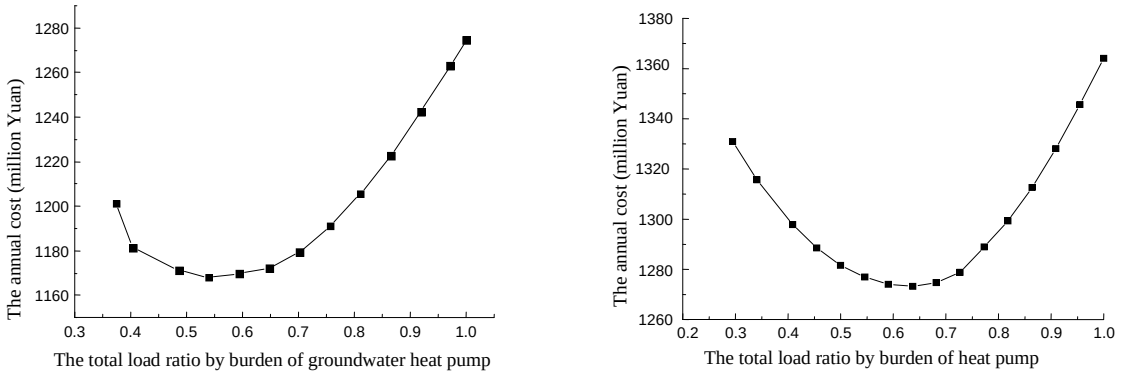
All The coal quantity of conversion and annual cost of the combined heat-supply system varied with the allocation proportion. The paper determined the optimal allocation proportion and studied the influence on the optimal allocation proportion due to the different climate areas. The paper takes the residential district with heating area of three hundred thousand square meters in Shenyang and Harbin respectively as the research object. The paper analyzed and calculated the energy consumption and the annual cost of the groundwater heat pump and coal-consuming boiler under the condition of different proportion. In order to more clearly show that various areas have influence on the allocation proportion of the combined heat source, the paper selects the same square thermal index of 50.9 W/m^2. Meanwhile, comply with the principle of single variable, other factors, such as coal price, electricity price and the initial investment of per unit area remaining constant. That is to say the influence of the various areas on these factors can be ignored. In the practical engineering, the initial investment of the groundwater heat pump is set as 200Yuan /m^2 and the initial investment of coal-consuming boiler is set as 80 Yuan /m^2.Meanwhile, electricity price of 0.5 Yuan / degrees, coal prices is 950Yuan / ton and so on [4]. With the formula (1) ~ (4), the energy consumption and economy of the combined heat-system are analyzed. The results are shown in Figure1and Figure2.



(a) Energy consumption of the combined system in Shenyang (b) Energy consumption of the combined system in Harbin

Figure 1.Change curve about converted standard coal quantity of total energy consumption.

The change curve of total energy consumption based on the combined heat-system (Figure 1) shows that the standard coal quantity of total conversion decreases gradually with the increase of the total load ratio by burden of the heat pump. A smaller proportion of the load corresponding to the larger change rate, the curve gradually becomes slow. When a larger proportion of load is corresponding to the smaller change rate the curve tends to level. Meanwhile, the standard coal quantity of total conversion change hardly with the increase of the ratio by burden of the heat pump.



(a) Annual cost of complementary heat source in Shenyang (b) Annual cost of complementary heat source in Harbin

Figure 2.The change curve of annual cost

Figure2 (a) is change curve about annual cost for the heating areas of 300000 square meters in Shenyang changing with allocation proportion. The figure 2(a) shows the low load by burden of groundwater heat pump is corresponding to the low annual cost of the system. The change range of the annual cost is from 48% to 65% and the ratio range is small. The allocation proportion of complementary heat source is 54 %+46 % coupled and the annual cost is lowest. But when the load ratio by burden of heat pump exceeds 70%, the change ranges of annual cost increases greatly. Figure 2(b) is change curve about annual cost for heating areas of 300000 square meters in Harbin. From Figure 2(b) you can see that with the increase of load ratio by burden of groundwater heat pump, the curve of annual cost based on complementary heating system is greatly decreased at first, the middle part changed modestly, and then increased to a great extent in the end. The range of curve in ratio range from 60% to 70% is relatively flat and the allocation proportion of complementary heat source is corresponding to 64 %+36 % with the lowest annual

cost in the Figure. The economic analyses shows that only change of the heating areas can lead the change of the average number of duration hours by compared with Shenyang and Harbin.

4. Discussion

Based on the analysis of energy consumption in this paper, the allocation proportion corresponding with the low total energy consumption is set as the first important factor of the optimal allocation proportion for the combined heating supply system. At the same time, in addition to electricity or coal consumption of the main equipment such as heat pump or boiler at work, the other related ancillary equipment such as pumps, fans, and other energy consumption will also be included in the total energy consumption.

Coupled with economic analysis, only the initial investment and operation cost of heat source can be considered. The initial investment of groundwater heat pump and -boiler plant are involved in the initial investment of heat source. The annual operation cost includes the operation cost of groundwater heat pump and boiler plant. Due to the restricted condition having little influence on the results we study, we can do not consider temporarily the influence of the initial investment and annual operation cost for heat network and user in different allocation proportion.

Combined with the engineering example, the change curve of total energy consumption is analyzed based on the combined heating system (Figure 1).Single from the total energy consumption of the complementary heating system to analyze, the paper considers the problem of the annual supply heating quality with small change ranges when the load ratio by burden of the groundwater heat pump is too large. When the allocation proportion of the complementary heat source is selected, the load ratio by the burden of heat pump should be less than 80%.Not only is the running time of coal-consuming boiler too short with the obvious effect of the saving energy, accord with the annual significance of its existence, but also the initial investment of the whole system can be reduced. Lead to the various trend of annual cost curve for the same heating area along with the load ratio by burden of groundwater heat pump being on the increase, and then the allocation proportion of complementary heat source corresponding with the lowest annual cost also has a change by analyzing the change curve of annual cost. In practical engineering applications, combined with the local actual situation, according to the local actual equipment price, electricity price, fuel price and so on to recalculate and analyses, the optimal allocation proportion of complementary heat source is determined.

5. Conclusion

When the system operates in the optimal load distribution proportion, the initial investment of the heat source system can be reduced. Not only does greatly it reduce the total energy consumption, but prolongs the performance period of boiler, improves the utilization efficiency of the boiler as well.

The residential district with heating area of 300000 square meters, the load optimal allocation proportion of the groundwater heat pump and coal-consuming boiler is 54% and 46% in Shenyang and Harbin for 64% and 36%.Meanwhile, the system has the lowest annual cost and the best economy.

In the price system under the same conditions, the change trend of curves about total conversion energy consumption of standard coal quantity is similar with the different parts of the same heating area. The change trend of curves about annual cost is different and the allocation proportion corresponding with the lowest annual cost has a change.

Acknowledgements

This research was supported by National "Twelfth Five-Year" Science and Technology Support Program (2011BAJ05B02).

References

[1] Hu J.S, Meng H, Li Z.J.Analysis on Features and Energy consumption of Various Heating source,J. Applied Energy Technology,148(2010),46-49.

[2] Ni L, Tang Q.S, Li A.M. Analysis on Design Heating Load Ratio of Ground Source Heat Pump with AuxiliaryHeat Source,J. Journal of Refrigeration,31(2010),18-23.
[3]Zhu Y.L. The Technique andEconomyStudy of the Central Heating System with Secondary Peak-shaving Plants,D. Tianjin University, China, 2007,81pages.
[4] Kang Z.Q, Sun J.L, Meng Q. Analysis on Features and Energy consumption of Various Heating source,J. HVAC, 44(2014), 62-64.
[5] Xiao Y.J, Zhou D.M, Zhao L. Engineering Economics. Higher Education Press,China, 2004,pp.203-205.
[6] Sun J.H. Study of the suitability and Northeast region of the heating heat cold ways,D.Shenyang jianzhu University, China, 2012,63pages.